DOSSIER TECHNIQUE

SYSTÈME DE TRANSMISSION VIDÉO PAR FAISCEAU LASER

Comporte les documents suivants :

PC100 AND PC200 SERIES

PC100 Series

The PC100 series of Icw voltage Pockels cells is capable of being driven at frequzncies of up to 10 MHz. It uses ADP crystals in a configuration which is free from piezo-electric resonances.

Three models are avaible, the PC100/2, PC100/3 and PC100/4. The PC100/2 and PC100/4, are four cystal devices, with apertures of 2.5 mm and 4 mm respectively. These modulars have the advantage of a low drive voltage, and can be used over a wide range of wavelengths.

The PC100/3 is a two crystal device with a 2mm aperture. The configuration provides a high extinction ratio, and excellent temperature stability. The PC100/3 is manufactured to operate at a specific wavelength.

The PCI00 series is filled with index matching liquid to maximise the transmission through the modulator. Volume compensating bellows are fitted to remove internal pressure changes which may cause crystal stress, and the crystal configuration is optimised so that the effect of external temperature changes is minimised.

PC200 Series

The PC200 Series of low voltage Pockels cells is identical to the PC100 Series except thaï AD*P crystal is used instead of ADP. Three models are available, the PC200/2, PC200/3. and PC200/4. AD*P has a better infrared transmission than ADP and has a lower halfwave voltage. This allows the PC200 Series to be used for near-infrared applications, and is particularity suitable for modulation of YAG lasers.

Features

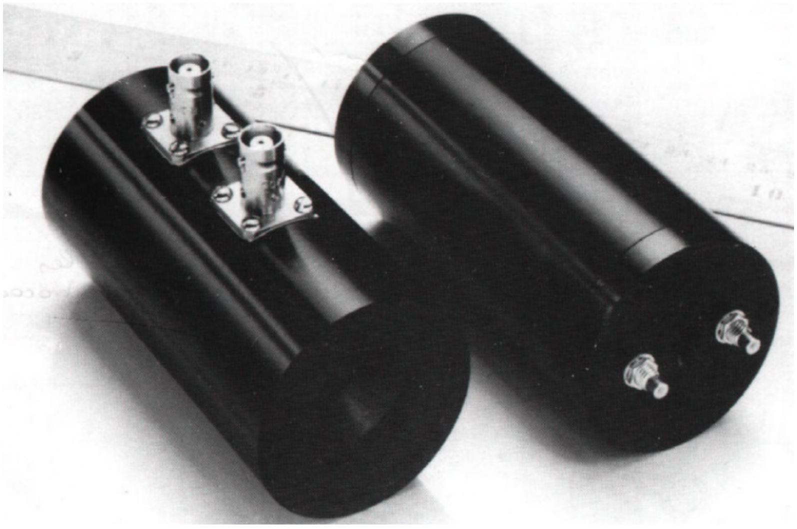
- Apertures from 2 mm to 4mm,
- Bandwiths to 10 MHz,
- No piezo-electric resonances,
- High extinction ratio,
- Good temperature stabililv,
- Index matching liquid filled,
- Pressure compensating bellows.

Applications

- Analogue or digital communications,
- Data te!emetry,
- High resolution digital recording for reprographics,
- Laser stabilisation,
- Digital beam deflection,
- 3-colour display systems,
- General CW laser modulation,
- Modulation of YAG lasers.

LOW VOLTAGE POCKELS CELLS

cadre 1 : Specifications.



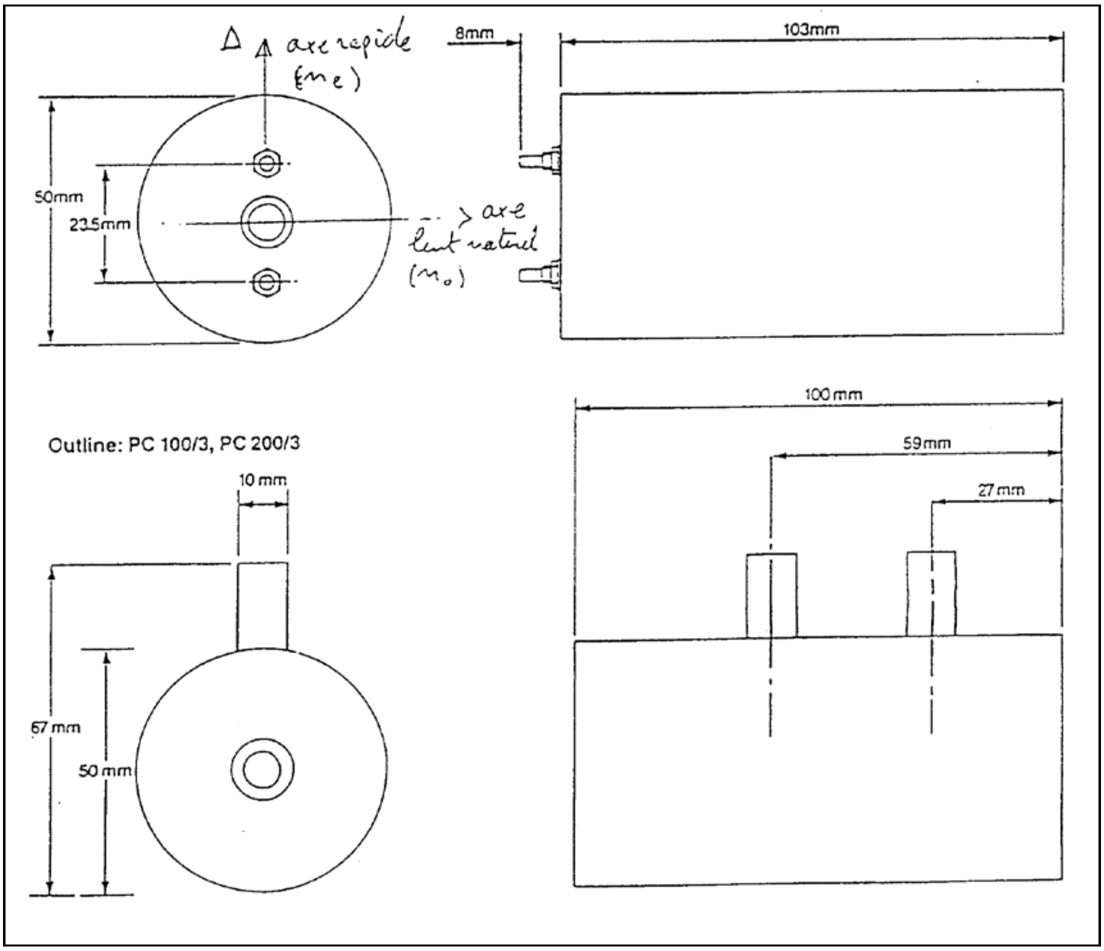
cadre 2 : Cellules de Pockels.

PC100 AND PC200 SERIES SPECIFICATIONS

Model	PC100/2	PC100/3	PC100/4	PC200/2	PC200/3	PC200/4
Cell diameter	50 mm	50 mm	50 mm	50 mm	50 mm	50 mm
Cell length	111 mm	103 mm	111 mm	111 mm	103 mm	111 mm
Aperture	2.5 mm	2 mm	4 mm	2.5 mm	2 mm	4 mm
Connectors	Conhex	HV BNC	Conhex	Conhex	HV BNC	Conhex
Capacitance	40 pF	20 pF	40 pF	60 pF	30 pF	60 pF
Halwave voltage at 633 nm	250V ± 25 V	400V ± 30 V	400V ± 40 V	160V ± 15 V	260V ± 25 V	260V ± 25 V
Maximum continuous applied voltage	500 V	500 V	500 V	500 V	500 V	500 V
Extinction ratio	> 100 :1	> 500 :1	> 100 :1	> 100 :1	> 500 :1	> 100 :1
Transmission with uncoated windows	> 80 %	> 80 %	> 80 %	> 80 %	> 80 %	> 80 %
Wavelength range	0.4 to 0.9 µm	0.4 to 0.9 µm	0.4 to 0.9 µm	0.4 to 1.2 µm	0.4 to 1.2 µm	0.4 to 1.2 µm
Crystal	ADP	ADP	ADP	AD*P	AD*P	AD*P
Number of crystals	4	2	4	4	2	4

cadre 3 : Spécifications cellules.

Indices naturels à 633 nm:
n_e = 1,475;
n_o = 1,516.



cadre 4 : Dimensions cellules.

VLA30 VIDEO LINEAR AMPLIFIER

cadre 5 : Alimentation VLA30.

Description

The VLA30 amplifier is a high performance output video amplifier covering the frequency range from d.c. to over 6 MHz. In addition, up to ± 250 V d.c. bias can be applied to a Pockels Cell without limiting the signal handling ability. Distorsion is low even at maximum output and frequency and recovery after overdriving is excellent. The output is short circuit proof.

Features

- Bandwith DC-6 MHz
- 250 Vpk-pk Output
- Rise time 70 ns.

VLA30 Specifications Input/Output Data

Output voltage	250Vpp at 240V a.c. mains
Capacitive loading	70pf differential corresponding to 1m cable and PC 100
Input coupling	d.c., ground, or a.c. (500Hz.)
Input voltage (nominal)	± 1Vd.c., 2Vpp a.c.
Input impedance	50 ohm nominal
Bias range	± 250V d.c.

Signal response

Sinewave 0-280Vpp	d.c. – 5.6MHz @ –3db min.
Sinewave 0-250Vpp	d.c. – 6.5MHz @ –3db typ.
Square wave rise and fall times (10%–90%). 0–260Vpp	>70ns

Mechanical Details

Temperature range	0°–40°C ambient air
Power supply VLA30	200,220,240V a.c., 50–60Hz, 330W
Power supply VLA30 (Con)	100,110,120V a.c., 50–60Hz, 330W
Dimensions	210mm×330mm×500mm
Weight	15kg. (Transit Wt. 19kg.)

cadre 6 : Spécifications.

Test Sheet

PRODUCT PERFORMANCE SPECIFICATIONS

MODULATORS	PC100/2	PC100/4	PC100/W	PC200/2	PC200/4	PC200/W
Apertures	2mm	4mm	2.5mm	2mm	4mm	2.5mm
Capacitance	<65pF		<55pF	<85pF		<65pF
Connectors	Conhex		HV BNC	Conhex		HV BNC
Halfwave Voltage @ 633nm	250V	400V		160V	260V	
Wavelength Range	0.4 µm to 0.9 µm			0.4 µm to 1.2 µm		
Maximum Voltage	500V					
Extinction Ratio (minimum)	>100:1		>500:1	>100:1		>500:1
Extinction Ratio (< 100mW, < 2mm beam dia)	>100:1	>300:1	>500:1	>100:1	>300:1	>500:1
Transmission - coated @ 633nm	90%		86%	90%		86%
- uncoated @ 633nm	84%		80%	84%		80%
Maximum Laser Intensity	50 W cm^{-2}					
Maximum Laser Power (using full aperture)	1.5W	6W	1.5W	1.5W	6W	1.5W
Diameter	50mm					
Length	111mm		103mm	111mm		103mm

Note: To achieve an extinction ratio of 100:1 at the NdYag (1.06) wavelength with the PC200 Series modulator, Power is limited to 300mW.

Serial Number PC 00/ -

Capacitance ____________pF

Extinction Ratio ____________:1 Using 10mW Argon (488nm) laser

DC Halfwave Voltage (@ 633nm) ____________V

Transmission ____________%

Beam Deviation ____________mrads

Test Engineer ________________________ Date ____________

- 7 - PCHK003

cadre 7.

Principe optoélectronique

δ Δϕλπd

A l'entrée d'un cristal biréfringent uniaxe, une vibration polarisée rectiligne se décompose en deux vibrations, appelées ordinaire (O) et extraordinaire (E), dirigées selon deux directions orthogonales qui sont les lignes neutres, OX et OY, du cristal.

Après traversée du cristal d'épaisseur *e*, ces vibrations présentent une différence de marche δ et une différence de phase (ou déphasage) ϕ:

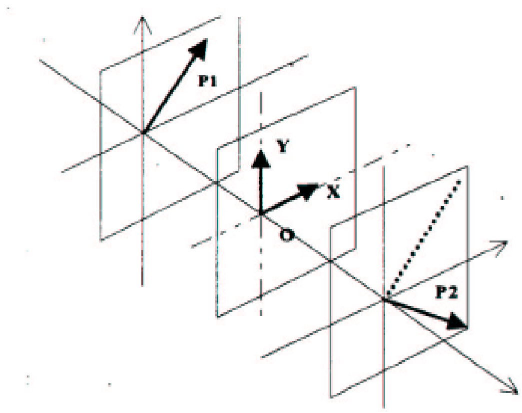
$$\delta = e.\Delta n \text{ et donc } \phi = (2\pi/\lambda).e.\Delta n \text{ avec } \Delta n = n_O - n_E$$

Dans la cellule de Pockels, la biréfringence est fonction de la tension U imposée au cristal:

$$\delta = K.U + \delta_0 \text{ et donc } \phi = (2\pi/\lambda).K.U + \phi_0 = N.U + \phi_0$$

où

- K est caractéristique de la cellule de Pockels.
- δ_0 est la différence de marche naturelle (ou résiduelle) en l'absence de tension
- ϕ_0 est le déphasage naturel (ou résiduel)



Les polariseurs sont représentés par leur direction privilégiée P1 et P2 et la cellule de Pockels par ses lignes neutres OX et OY.

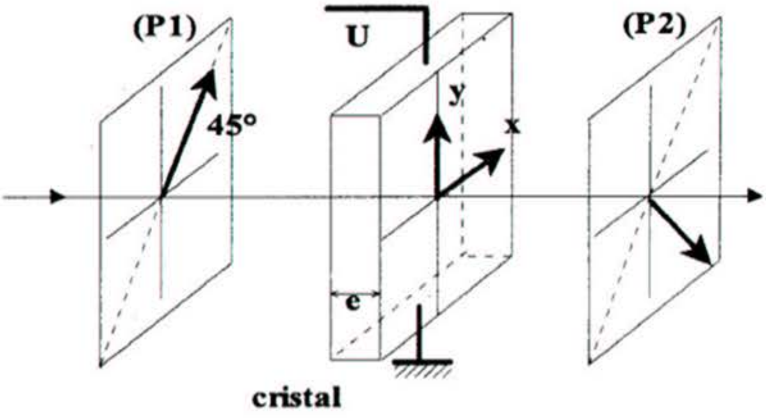
Si E_0 est l'amplitude de l'onde incidente ($I_{maxi}=E_0^2$) à l'issue de P1, alos l'amplitude résultatnte émergeant de l'analyseur est:

- $(E_0/2)(1+\exp(-j\ \phi))$ si P1 et P2 sont parallèles
- $(E_0/2)(1-\exp(-j\ \phi))$ si P1 et P2 sont croisés (perpendiculaires)

On en déduit l'intensité lumineuse I émergente:

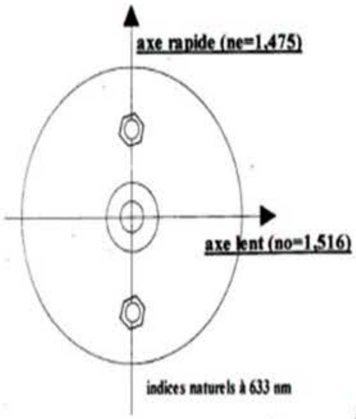
Pour une tension	Déphasage	Différence de marche	Si P_1 et P_2 (//)	Si P_1 et P_2 ($\perp$)
particulière U_1 telle que	$0+2.k.\pi$	$0+k\lambda$	I_{maxi}	0
particulièreU_2 telle que	$\pi+2.k.\pi$	$\frac{\lambda}{2}+k\lambda$	0	I_{maxi}
quelconque U telle que	$\varphi+2.k.\pi$	$\delta+k\lambda$	$I = I_{maxi} \cdot \cos^2 \frac{\phi}{2}$	$I = I_{maxi} \cdot \sin^2 \frac{\phi}{2}$

La cellule de Pockels étudiée (PC200/2) est de type transversale (cf schéma ci–après)



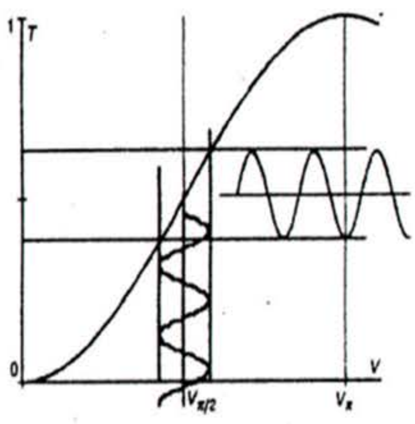
En champ nul, $\Delta n = n_E - n_O$.
L'application d'une tension $V=V_{bias}$, entre les plans z=0 et z=e, induit un champ électrique E parallèle à l'axe Oz.

La biréfringence est donnée par la relation suivante:
$\Delta n = n_0^3 \, r_{633} \, (V/e)$



A Pockels PC200/2 (Optilas)

Effets électro-optiques (POCKELS)



A modulation de l'intensité lumineuse par un modulateur électro optique.

HIGH SPEED SILICON DETECTOR

MODEL: DET1-SI

Thorlabs' detector package is a ready-to-use high speed photodetector. The unit comes complete with a photodiode and an internal 22.5V bias battery enclosed in a rugged aluminum housing. The housing mounts directly to our line of positioning devices. Models span the spectral range from 190 to 1800nm with risetimes below 2ns.

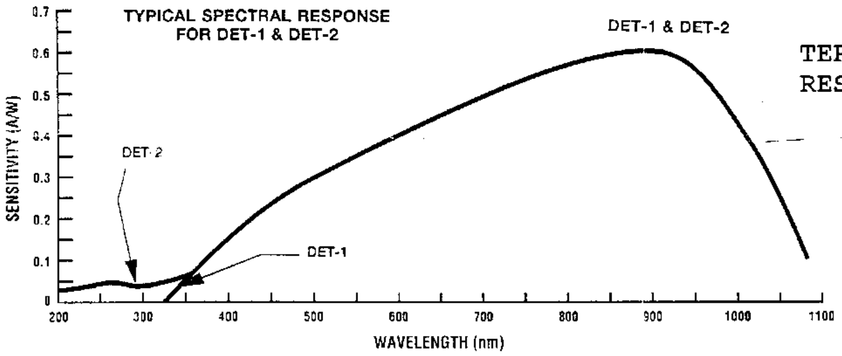
DETECTOR TYPE: **SILICON PIN DIODE**
SPECTRAL RESPONSE: **350-1100NM**
RISETIME: **<10nm (50 Ohms)**
FALLTIME: **SAME AS RISETIME**
CAPACITANCE: **25pF**
NEP: **1.2E-14 W/Hz (@ 20V BIAS)**
DARK CURRENT: **20nA (@ 20V BIAS)**
ACTIVE AREA: **13.7 sq. mm**

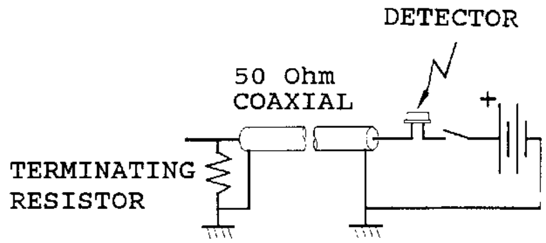
HOUSING: **BLACK ANODIZED ALUMINUM**
HOUSING SIZE: **0.75" X 1.3" X 2"**
SIGNAL CONNECTOR: **BNC, DC COUPLED**
BIAS BATTERY: **22.5V BATTERY**
MOUNTING: **#8-32 TAPPED HOLE**
DIODE SOCKET: **T05 ANODE MARKED**
DAMAGE THRESHOLD CW: **100mW**
DAMAGE 10ns PULSE: **0.5J/(sq. cm)**

TERMINATING RESISTOR SUPPLIED BY USER

The following paragraph is presented as a guide to assist in the choice of the user supplied terminating resistor, see schematic below. This resistor multiplied by 3 times the total capacitance of the detector gives an approximate value for the system risetime.

Use the plot to determine the radiant sensitivity that corresponds to the wavelength of your signal, multiply this sensitivity by your lowest optical signal expressed in watts. Substitute this photo-current into Ohm's law to determine your minimum signal voltage for a given terminating resistor. Minimize the terminating resistor to maximize the bandwidth (bandwidth=0.35/risetime) of the detector. Note, if the detector is connected directly to an oscilloscope with a 1M ohm input resistance, the system risetime will be on the order 0.1 milliseconds.





CATHODE IS MARKED ON BOTH

Now Available
Germanium Detectors 800-1800nm
Call for more information

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PO BOX 366 NEWTON, NJ 07860

cadre 8 : Détecteur silicium.

HIGH SPEED SILICON DETECTOR

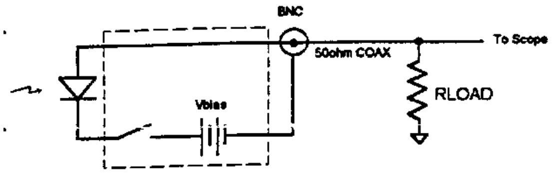
DET2-SI High-Speed Silicon Detector

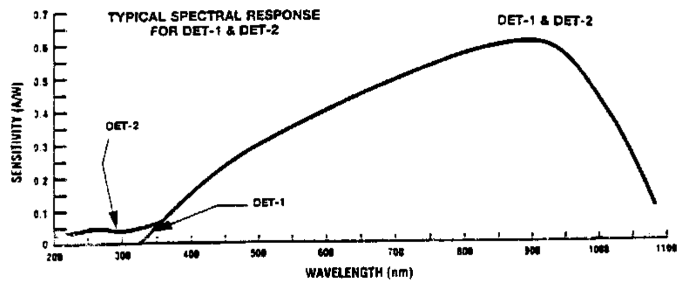
Thorlab's DET2-SI is a ready-to-use high-speed photo detector. The unit comes complete with a photo diode and internal 22.5V bias battery enclosed in a ruggedized aluminum housing. The DET2 uses a quartz window to extend the detector response into the UV. An 8-32 tapped hole is provided on the base of the housing to mount the detector directly to a Thorlabs positioning device (1/2" post holder, mounting plates, etc.). The DET series of detectors covers a spectral range of 190 to 1800nm with rise times below 1ns.

SPECIFICATIONS:

Detector:	Silicon PIN
Spectral Response:	185 - 1100nm
Peak Wavelength:	920nm ± 50nm
Rise / Fall Time[1]:	≤ 1ns
Diode Capacitance:	1.8 pF
NEP:	5×10^{-14} W / √Hz
Dark Current:	2.5 nA
Active Area:	$1.0 mm^2$ (round)
Linearity Limit:	1mW
Housing:	Black Anodized Aluminum
Size:	0.75" x 1.3" x 2"
Output:	BNC, DC-Coupled
Bias:	22.5V Battery
Mounting:	8-32 Tapped Hole
Diode Socket:	TO-5, Anode Marked
Damage Threshold:	100mW CW $0.5 J / cm^2$ (10 ns pulse)

Notes:
1. 50Ω Terminating Resistor





Thorlab's DET series are ideal for measuring both pulsed and CW light sources. Each DET includes a reverse-biased PIN photo diode, bias battery, and an ON/OFF switch packaged in a ruggedized housing. The BNC output signal is the direct photo current out of the photo diode anode and is a function of the incident light power and wavelength. The responsivity, $\Re(\lambda)$, can be read from Figure 1 to estimate the amount of photocurrent to expect. Most users will wish to convert this photocurrent to a voltage for viewing on an oscilloscope or DVM. This is accomplished by adding an external load resistance, R_{LOAD}. The output voltage is derived as:

$$V_O = P * \Re(\lambda) * R_{LOAD}.$$

The bandwidth, f_{BW}, and the rise-time response, T_R, are determined from the diode capacitance, C_J, and the load resistance, R_{LOAD}:

$$f_{BW} = 1 / (2\pi * R_{LOAD} * C_J), \quad T_R = 0.35 / f_{BW}$$

For maximum bandwidth, we recommend using a 50Ω coax cable with a 50Ω terminating resistor at the end of the coax. This will also minimize ringing by matching the coax with its characteristic impedance. If bandwidth is not important, you can increase the amount of voltage for a given input light by increasing the R_{LOAD}.

Also Available: Large Area Silicon detectors, Germanium Detectors (800- 1800nm), and amplified detectors.

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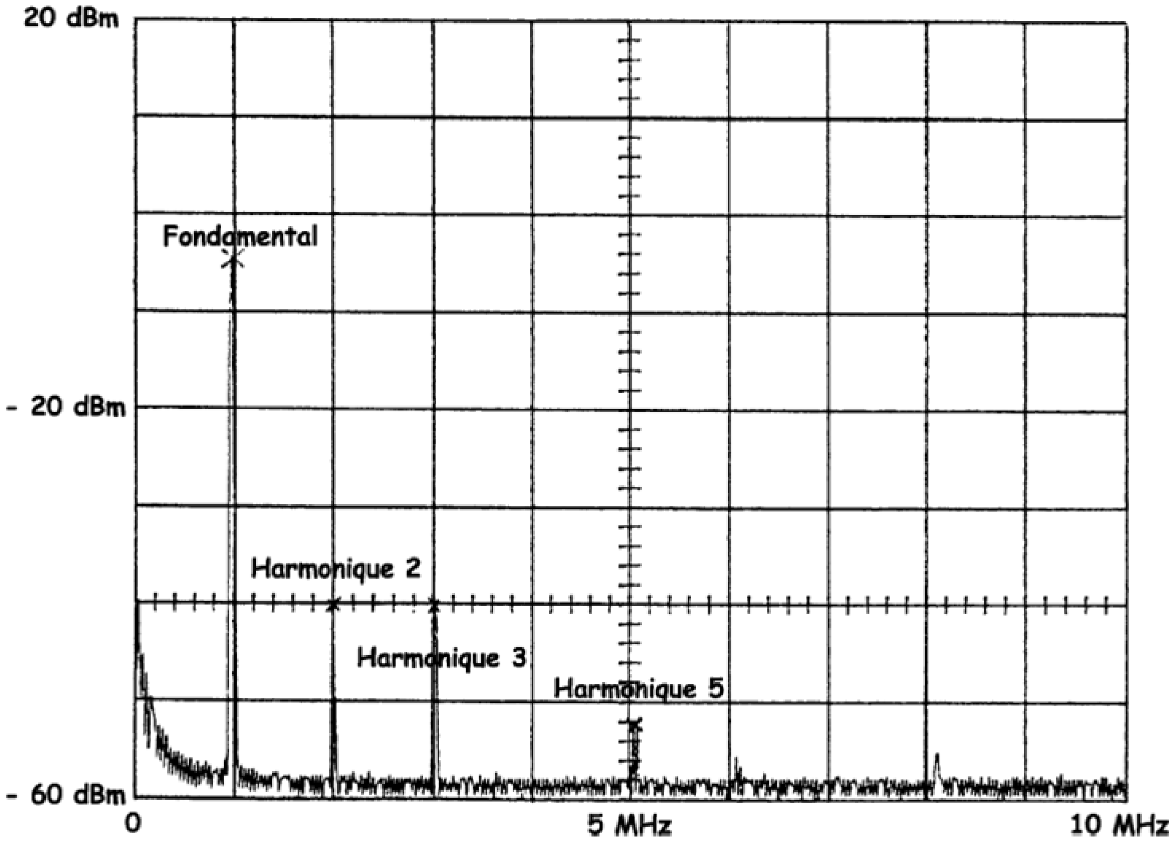
cadre 9 : Détecteur silicium.

Mesure de la distorsion harmonique

Cette mesure, couramment utilisée en électronique nous renseigne sur :

- La qualité d'un oscillateur sinusoïdal
- La linéarité d'un amplificateur (analyse spectrale de la sortie si l'entrée est sinusoïdale).



Ce signal contient :

- Le fondamental : F = -5dBm = 125mV (valeur efficace)
- L'harmonique 2 : H2 = -40dBm = 2.2mV
- L'harmonique 3 : H3 = -40dBm = 2.2mV
- L'harmonique 5 : H5 = -52dBm = 0.6mV

Par définition, le taux de distorsion harmonique s'écrit :

$$td = \frac{\sqrt{H_2^2 + H_3^2 + ...}}{F} = \frac{\sqrt{2.2^2 + 2.2^2 + 0.6^2}}{125} = 0.025 = 2.5\%$$

Le tableau ci-dessous donne pour une charge de 50ohms les valeurs efficaces par rapport aux différentes puissances en dBm.

dBm - volts - watts conversion

(50-ohm system)

dBm	V	P_o	dBm	V	P_o	dBm	mV	P_o	dBm	µV	P_o
+53	100.0	200W	0	.225	1.0 mW	-49	0.80		-98	2.9	
+50	70.7	100W	-1	.200	.80 mW	-50	0.71	.01 µW	-99	2.51	
+49	64.0	80W	-2	.180	.64 mW	-51	0.64		-100	2.25	.1 pW
+48	58.0	64W	-3	.160	.50 mW	-52	0.57		-101	2.0	
+47	50.0	50W	-4	.141	.40 mW	-53	0.50		-102	1.8	
+46	44.5	40W	-5	.125	.32 mW	-54	0.45		-103	1.6	
+45	40.0	32W	-6	.115	.25 mW	-55	0.40		-104	1.41	
+44	32.5	25W	-7	.100	.20 mW	-56	0.351		-105	1.27	
+43	32.0	20W	-8	.090	.16 mW	-57	0.32		-106	1.18	
+42	28.0	16W	-9	.080	.125 mW	-58	0.286				
+41	26.2	12.5W	-10	.071	.10 mW	-59	0.251		**dBm**	**nV**	
+40	22.5	10W	-11	.064		-60	0.225	.001 µW	-107	1000	
+39	20.0	8W	-12	.058		-61	0.200		-108	900	
+38	18.0	6.4W	-13	.050		-62	0.180		-109	800	
+37	16.0	5W	-14	.045		-63	0.160		-110	710	.01 pW
+36	14.1	4W	-15	.040		-64	0.141		-109	640	
+35	12.5	3.2W	-16	.0355					-112	580	
+34	11.5	2.5W				**dBm**	**µV**		-113	500	
+33	10.0	2W	**dBm**	**mV**		-65	128		-114	450	
+32	9.0	1.6W	-17	31.5		-66	115		-115	400	
+31	8.0	1.25W	-18	28.5		-67	100		-116	355	
+30	7.10	1.0W	-19	25.1		-68	90		-117	825	
+29	6.40	800 mW	-20	22.5	.01 mW	-69	80		-118	285	
+28	5.80	640 mW	-21	20.0		-70	71	.1nW	-119	251	
+27	5.00	500 mW	-22	17.9		-71	65		-120	225	.001 pW
+26	4.45	400 mW	-23	15.9		-72	58		-121	200	
+25	4.00	320 mW	-24	14.1		-73	50		-122	180	
+24	3.55	250 mW	-25	12.8		-74	45		-123	160	
+23	3.20	200 mW	-26	11.5		-75	40		-124	141	
+22	2.80	160 mW	-27	10.0		-76	35		-125	128	
+21	2.52	125 mW	-28	8.9		-77	32		-126	117	
+20	2.25	100 mW	-29	8.0		-78	29		-127	100	
+19	2.00	80 mW	-30	7.1	.001mW	-79	25		-128	90	
+18	1.80	64 mW	-31	6.25		-80	22.5	.01 nW	-129	80	
+17	1.60	50 mW	-32	5.8		-81	20.0		-130	71	.1fW
+16	1.41	40 mW	-33	5.0		-82	18.0		-131	61	
+15	1.25	32 mW	-34	4.5		-83	16.0		-132	58	
+14	1.15	25 mW	-35	4.0		-84	11.1		-133	50	
+13	1.00	20 mW	-36	3.5		-85	12.9		-134	45	
+12	.90	16 mW	-37	3.2		-86	11.5		-135	40	
+11	.80	12.5 mW	-38	2.85		-87	10.0		-136	35	
+10	.71	10 mW	-39	2.5		-88	9.0		-137	33	
+9	.64	8 mW	-40	2.25	.1µW	-89	8.0		-138	29	
+8	.58	6.4 mW	-41	2.0		-90	7.1	.001 nW	-139	25	
+7	.500	5 mW	-42	1.8		-91	6.1		-140	23	.01fW
+6	.445	4 mW	-43	1.6		-92	5.75				
+5	.400	3.2 mW	-44	1.4		-93	5.0				
+4	.355	2.5 mW	-45	1.25		-94	4.5				
+3	.320	2.0 mW	-46	1.18		-95	4.0				
+2	.280	1.6 mW	-47	1.00		-96	3.51				
+1	.252	1.25 mW	-48	0.90		-97	3.2				

$$P = \frac{U_{eff}^2}{R}$$

$$P(dBm) = 10.\log\left(\frac{P}{1.10^{-3}}\right)$$

$$U_{eff}^2 = R.1.10^{-3}.10^{\frac{P(dBm)}{10}}$$

$$U_{eff} = \sqrt{R.1.10^{-3}.10^{\frac{P(dBm)}{10}}}$$

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External Modulators

When data rates were in the low gigabit range and transmission distances were less than 100 km or so, most fiber optic transmitters used directly modulated lasers. However, as data rates and span lengths grew, waveguide chirp, caused by turning a laser on and off, limited data rates. Dispersion problems resulted when the wavelength chirp widened the effective spectral width of the laser. A laser source with no wavelength chirp and a narrow linewidth provide one solution to the problem. This solution took the form of external modulation which allows the laser to be turned on continuously; the modulation is accomplished outside of the laser cavity.

Theory of Operation

An external modulator restrains the light, functioning like an electrically activated shutter. As analog devices, external modulators allow the amount of light passed to vary from some maximum amount (P_{MAX}) to some minimum amount (P_{MIN}). Other key terms related to external modulators include:

Vp: This is the voltage required to take the response function through ½ cycle or 180°.

Bias Point: The DC point around which the modulation signal swings.

Insertion Loss: The amount of loss from the light injected by the laser at the peak of the waveform. This usually amounts to 3-5 dB. Keep in mind that operating at the usual bias point will introduce an additional 3 dB of loss for a total insertion loss of 6 to 8 dB. (See Figure 5 for details.)

P_{MIN}: The minimum light output from the external modulator. Usually about 5% of the maximum value.

P_{MAX}: The maximum light output from the external modulator. Usually 3 to 5 dB less than the laser input.

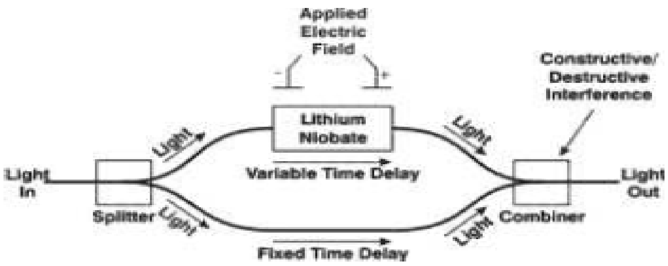
P_{AVG}: The average light out of the external modulator. Usually 3 dB less than P_{MAX} if driven by a 50% duty cycle waveform.

Lithium Niobate Amplitude and Phase Modulators

The popularity of lithium niobate ($LiNbO_3$) as a material used in external modulators results from its low optical loss and high electro-optic coefficient. This coefficient refers to the electro-optic effect, which occurs in some materials such as lithium niobate, in which the refractive index of the material changes in response to an applied electric field. The refractive index of the material causes light to travel at a speed inversely proportional to the refractive index of the material. Thus, if we could suddenly increase the refractive index of a material, we would slow the light beam down and vice versa.

Figure 1 shows the block diagram of a typical external modulator. The input light enters the external modulator via the input fiber. The light is first splits into two fibers using an optical splitter. The top fiber path travels through a length of $LiNbO_3$ crystal. The light in the bottom fiber experiences a fixed delay. After the light travels through the lithium niobate crystal and the fixed length of fiber, an optical combiner merges the two fiber paths. The light travels through identical path legs.

Figure 1 - Typical Lithium Niobate ($LiNbO_3$) Optical Modulator

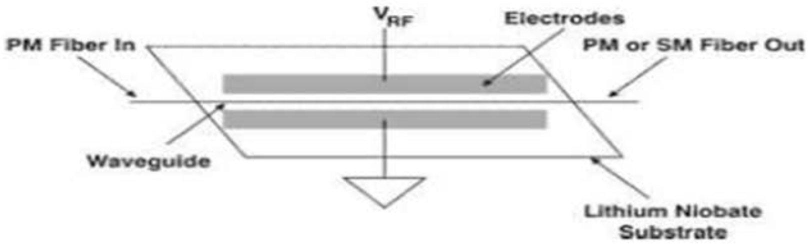


By applying an electric field to the material, its refractive index changes. We now see that if the time delay through the fixed fiber and the $LiNbO_3$ crystal is equal, the light will be in phase when it reaches the output optical combiner. Due to the nature of light, we see that since the light in both legs are in phase, they will constructively add to form the maximum possible output. The refractive index and the speed of light change as the applied voltage changes. When the speed changes enough to delay the light by half of one wavelength, the light will be out of phase when it reaches the output 3 dB coupler. Now the light will destructively form, yielding a minimum possible output.

Building a waveguide in the substrate makes the device suitable for use in fiber optic devices. As with optical fiber itself, this is accomplished by introducing dopant materials into the area that will become the waveguide. Doping raises the refractive index of the waveguide relative to the surrounding substrate while maintaining optical transparency. Once accomplished, the waveguide will contain the light by the principles of total internal reflection. If the dimensions of the waveguide remain consistent with the dimensions of the core of a single-mode fiber, about nine microns in diameter, then light will efficiently couple into and out of the waveguide. This basic design proves useful in a fiber optic system.

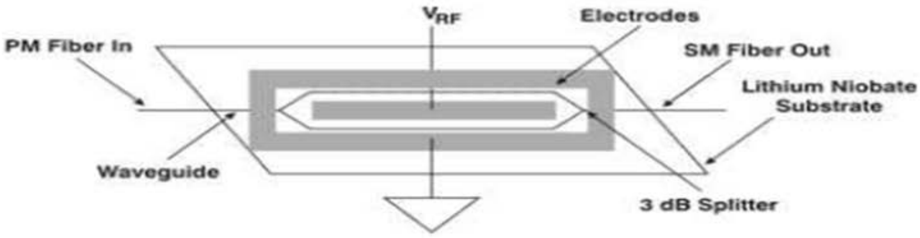
Figure 2 illustrates the simplest type of external modulator, a phase modulator. The phase modulator has a single optical input of polarization maintaining (PM) fiber and a single optical output of PM or single-mode (SM) fiber. In a simple phase modulator, two electrodes surround the waveguide. The bottom electrode is grounded while the top electrode is driven by an outside voltage signal. As the voltage on the top electrode changes, the refractive index of the waveguide changes accordingly, alternating the light as the refractive index rises and falls. While this modulates the phase of the light, the output intensity remains unchanged. This modulation overcomes stimulated brillioiun scattering, the easiest fiber nonlinearity to trigger. The SBS threshold can increase by as much as 10 dB because phase modulating the light effectively widens the optical energy.

Figure 2 - Simple Phase Modulator



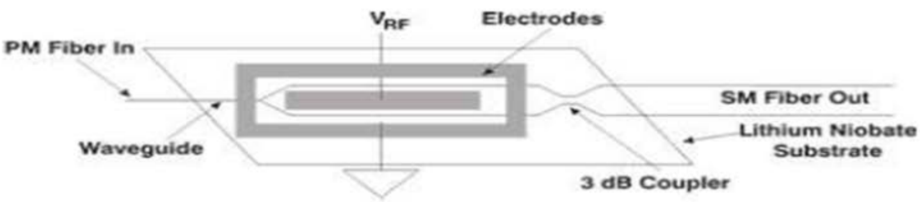
<u>Figure 3</u> shows a more internally complex device. It has the same input and output fiber setup as the simple phase modulator. However, after the light enters the lithium niobate waveguide, it optically splits into two paths using a fiber optic coupler designed into the substrate. These two paths travel for a distance and then recombine using another fiber optic coupler. If the light waves are in phase, they will add constructively to produce a large output on the output leg. If they are out of phase, destructive interference yields little or no output. The two paths of light travel through sets of electrodes arranged so that they have opposite effects on the two paths. By applying an external voltage, the refractive index of one path will rise while the refractive index of the other path falls. This causes the output optical amplitude to vary as the light from the two paths moves from constructive addition to destructive interference.

Figure 3 - Single Output Intensity Modulator



A third type of external modulator, illustrated in <u>Figure 4</u>, resembles the modulator shown in Figure 3. However, in this case, a 3 dB coupler forms at the output, giving two output fibers rather than one. The light amplitude of the two output legs will move opposite of each other. When the light level of one leg increases, the light level of the other leg decreases. The dual output modulator, which provides two out of phase outputs works best in analog drive situations.

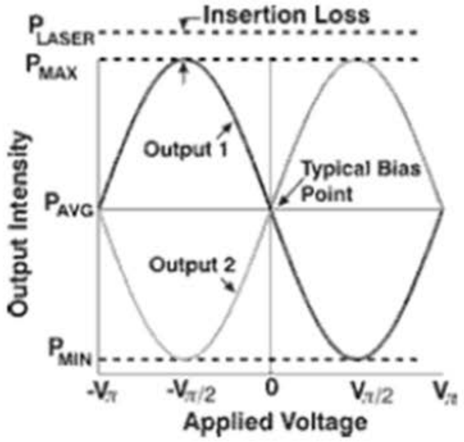
Figure 4 - Dual Output Intensity Modulator



<u>Figure 5</u> shows the typical raised sine function response of the dual output intensity modulator. The modulator operates around zero Volts bias. At zero Volts bias, the output intensity of both output legs is equal. As the applied voltage increases slightly, the intensity of output 2 increases, while the intensity of output 1 decreases. This continues until the voltage reaches $V_{p/2}$. At that point, the intensity of output 2 will be at a maximum and the intensity of output 1 will be at a minimum. This sine function response repeats as the applied voltage increases or

decreases. Usually, modulator designers exploit the response nearest zero Volts bias.

Figure 5 - Dual Output External Modulator Response



Digital Operation

In the simple applications, an external modulator transmits a digital data stream, toggling the drive voltage between $-V_{p/2}$ and $V_{p/2}$. This causes the output intensity to swing from maximum to minimum utilizing maximum modulation depth.

Analog Operation

External modulators may also be used to transmit analog signals. This modulation scheme may require extensive stabilization and linearization. Stabilizing the bias point at exactly the 50% point minimizes that second-order distortion. However, a third-order distortion remains. A small drive signal may yield a response that does not require linearization. CATV applications require predistortion of the signal to remove the effects of third-order distortion when sending 80 or 110 channels.

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COVEGA

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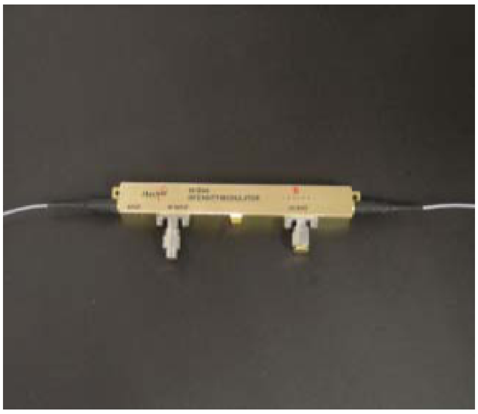
Mach-40™ 005: 40 Gb/s Fixed Chirp Intensity Modulator with external DC Bias

7.1.2.SP.0005 Rev F Preliminary Model

Description

The 40 Gb/s Intensity Modulator with External DC Bias is a revolutionary, high performance External Optical Modulator designed for customers developing next generation 40G transmission systems. The 40 Gb/s Intensity Modulator with External DC Bias is based on Titanium-indiffused z-cut Lithium Niobate and uses a Mach-Zehnder interferometric architecture. The 40 Gb/s Intensity Modulator has sufficient bandwidth for customers requiring greater bandwidth to implement today's most demanding FEC schemes.

The 40 Gb/s Intensity Modulator with External DC Bias is ideal for both NRZ and RZ data format solutions. The 40 Gb/s Intensity Modulator with External DC Bias is a single-ended drive configuration with a fixed chirp coefficient of +/-0.7 and an industry leading low RF drive voltage.



Applications

- ✓ High-Speed Data Communications
  - SONET OC-768 Interfaces
  - SDH STM-256 Interfaces
  - WDM transmission at 40 Gb/s
- ✓ Undersea communications
- ✓ Internet router interfaces
- ✓ High-speed test equipment

Features

- → Superior Frequency Performance
- → Industry Leading Low Drive Voltage
- → Long-Term Bias Stability
- → Fixed Non-Zero Chirp
- → Hermetic Packaging - High Reliability
- → C & L Band Operation

Ordering Information

Mach-40 005-40-X-X-X-NS

Part #	**Bandwidth**	**Output Fiber Type**	**Input Connector**	**Output Connector**	**Bias Operating Point**	
005	40 = 40 GHz*	S = SMF*	S = SC/PC*	S = SC/PC*	NS = Negative Slope	
		P = PMF	B = Bare Fiber	B = Bare Fiber		
			F = FC/uPC	F = FC/uPC		
			L = LC/PC	L = LC/PC		
			A = FC/aPC	A = FC/aPC		
			M = Mu	M = Mu		

* Default options unless otherwise specified

Data Sheet
September 2003

EOSPACE

Lithium Niobate 10 to 20 Gb/s Modulators

Ultra-low Loss Intensity Modulators for 10, 12.5, and 20 Gb/s Communication Systems and Wideband Analog Applications

EOSPACE's modulators for use in 10, 12.5, or 20 Gb/s digital communication systems and high bandwidth analog applications offer industry leading low optical insertion loss. This low insertion loss feature is maintained over the entire optical C&L bands.

The low drive voltage requirements of these integrated optical modulators make them compatible with a wide variety of commercial drivers available for high bandwidth systems. The slim and sleek profile of the modulator package allows the use of many mounting configurations of line and circuit cards. A single ended K-connector at the data port provides a usable bandwidth of greater than 20 GHz.

The availability of a wide variety of options for this product line allows a user to customize these devices for virtually any wideband application. These custom options include; customer specified fiber and fiber connector configurations, wavelength operations centered at other than 1550 nm (e.g. 1.06 and 1.3 microns), an integrated photodiode for optical power monitoring and bias control, and custom insertion loss and drive voltage requirements. 1x2 modulators are also available as a custom option.

A key product in this family has been optimized for extended environmental performance for the stringent requirements of the aerospace industry.

EOSPACE's modulators are based on our proprietary exceptionally high performance lithium niobate technology developed over the last 20 years for demanding aerospace applications.

Key Features

- Very low insertion loss
- Wide bandwidth and extended frequency performance
- Low drive voltage
- 0 chirp (x-cut) or –0.7 chirp (z-cut) versioi
- Low loss operation over entire C&L band:
- Separate RF and DC bias electrodes
- Compact package

Applications

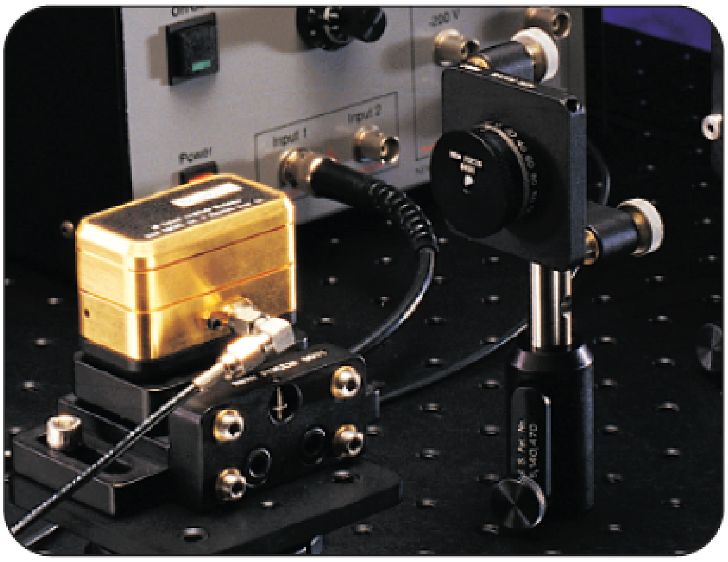
- 12.5+ Gb/s digital data communications
  - SONET OC-192 with FEC
  - SDH STM-64 with FEC
  - 10 Gb/s WDM transmission systems
- Wideband analog signal transmission
- RZ optical pulse formation
- Long haul terrestrial links
- Undersea links
- Ultra-high speed test equipment

Options

- Industry leading ultra-low insertion loss
- 0.8, 1.06, or 1.3 micron operation
- Dual-band (1.3/1.55 µm operation)
- Extended environmental performance for aerospace applications
- Ultra-low drive voltage
- 1x2 dual complementary optical outputs
- Higher optical power handling capability

Amplitude Modulators

- *Innovative design minimizes thermal birefringence*
- *High-quality lithium niobate crystals guarantee high contrast and low drive voltages at visible wavelengths*
- *Can be used as electronically variable wave plates*



Attenuating a laser beam with a Model 4104 amplitude modulator. The beam passes through the modulator followed by a polarizer (page 75). A Model 3211 broadband-modulator driver is used to drive the modulator.

New Focus™ amplitude modulators are specifically designed for high performance at modulation frequencies of up to 200 MHz. The Model 4102/4 broadband amplitude modulator can be operated from DC to 200 MHz. The Model 4101/3 is a resonant device that can be built to operate at any frequency from 0.01 to 200 MHz.

The crystals in these modulators are mounted at 45° so that your input polarization can be either vertical or horizontal. To minimize thermal birefringence, we use two matched crystals arranged in series. This results in amplitude modulators that exhibit less than 1 mrad/°C of temperature-dependent polarization rotation.

Since our modulators don't include external polarizers, they can be used as electronically variable wave plates. To use the device as an amplitude modulator, a polarizer is needed at the output. (See page 75 for our polarizers.)

The Model 4101/3 can be driven with a low-voltage function generator or the Model 3363 resonant-modulator drivers (page 72). The Model 4102/4 can be driven using our Model 3211 broadband-modulator drivers (page 70) with a function generator. Call us or visit the support section of our website for driver recommendations.

Technical Note

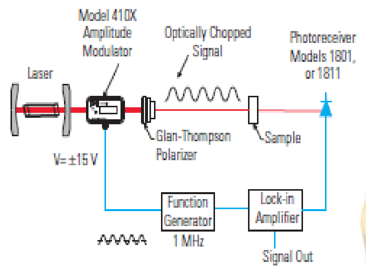
Extinction Ratio

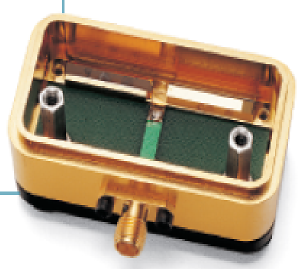
The extinction ratio of an amplitude modulator is the ratio between the optical power at maximum and minimum transmission. A high extinction ratio indicates a good modulator. For our Model 410X modulators, the extinction ratio is limited by refractive-index distortions in the electro-optic crystals that impart wavefront distortion to the optical beam. For these devices, the on:off extinction ratio is typically 50:1 for a 0.5-mm-diameter beam. Higher values can be achieved by focusing your beam.

Technical Note

Optical Chopping Using Our Modulators

One application of these modulators is high-frequency optical chopping. Although mechanical choppers are frequently used, they modulate the optical intensity at rates of only a few kilohertz. This frequency is often not high enough to get away from the 1/f noise of the detection system. An optical amplitude modulator, such as the Model 410X can be used to chop the beam at 1 MHz, thus giving you shot-noise-limited detection.





New Focus™ minimizes thermal drift by using two matched crystals to cancel polarization-rotation effects to less than 1 mrad/°C.

Type	Broadband AM	Broadband AM	Resonant AM	Resonant AM
Wavelength	500–900 nm	1.0–1.6 µm	500–900 nm	1.0–1.6 µm
Operating Frequency†	DC–200 MHz	DC–200 MHz	0.01–250 MHz†	0.01–250 MHz†
Maximum V_π	195 V @ 633 nm	300 V @ 1 µm	19 V @ 633 nm	30 V @ 1 µm
Material	$MgO: LiNbO_3$	$LiNbO_3$	$MgO: LiNbO_3$	$LiNbO_3$
On:off Extinction Ratio (typical†††)	50:1	50:1	50:1	50:1
Max. Optical Intensity††	2 W/mm^2 (532 nm)	1 W/mm^2 (1.3 µm)	2 W/mm^2 (532 nm)	1 W/mm^2 (1.3 µm)
Aperture	2 mm	2 mm	2 mm	2 mm
RF Bandwidth	200 MHz	200 MHz	2–4% freq.	2–4% freq.
RF Connector	SMA	SMA	SMA	SMA
Recommended RF Driver Models[1]	3211	3211	3363	3363
Impedance	10 pF	10 pF	50 Ω	50 Ω
Maximum RF Power	10 W	10 W	1 W	1 W
VSWR	-NA-	-NA-	<1.5	<1.5
Metric Versions	Add M to Model #	Add M to Model #	Add M to Model #	Add M to Model #
Model #	**4102**	**4104**	**4101**	**4103**
Price*	$3,750	$3,750	$4,500	$4,500
Price, 3-yr Extended Warranty[2]*	$425	$425	$425	$425

† For Model 4101/3, specify the resonant frequency when ordering.
†† The maximum optical intensity varies with wavelength.
††† Typical value for a 0.5-mm-diameter beam.
(1) See pages 70–73 for information about RF drivers for our modulators.
(2) See our terms and conditions of sale for more details.

Related Products: SMA-to-BNC Adapters (page 74) ▪ Polarizers (page 75) ▪ Four-Axis Tilt Aligner (page 74) ▪ Drivers (pages 70–73) ▪ Big Jacks (page 75)

Definitions of Characteristics (page 59)

**For international prices add 10%.*